Report No.

High Pressure Waterjet Cutting Industrial Needs Survey

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This report presents the results of a survey conducted by personnel of the National Center for Excellence in Metalworking Technology (NCEMT) to assess the industrial needs in high pressure water jet cutting (WJC) technology. Survey forms were mailed to approximately 1400 individuals obtained from three mailing lists. The respondents included approximately 200 individuals associated with a variety of industries: 12% were WJC equipment suppliers, 40% were WJC users, and 48% were neither suppliers nor users. The survey addressed five specific areas of WJC technology:

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19. continued

- research and development,
- standards
- systems
- new products
- training and service.

The industrial needs were determined based on the consensus established from the respondents' answers to questions in the five major categories.

Results show that the need having the highest priority is the establishment of a database on WJC that contains the cutting parameters for a wide range of materials. Associated with this objective is the expressed need for an independent demonstration and test center for testing, data generation and operator training. A further need was found for establishing organized efforts in hardware development and research in mechanisms of cutting.

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1.0 INTRODUCTION

High pressure water jet cutting is a relatively new technology that offers a viable alternative for material cutting processes, particularly in applications where conventional techniques have failed. Since WJC is new to the metalworking industry, its full potential will require another five to ten years of evolution. A survey has been conducted to assist the development of the potential of WJC technology. This survey prioritizes the industrial needs in high pressure WJC, based on the opinions of individuals with a current practice or interest in this technology.

The methodology used to develop the industrial needs analyses consisted of:

I. Industry familiarization

   A. Attend meetings and conferences
   B. Discuss WJC with its practitioners
   C. Literature survey
      1. Popular and trade journals
      2. Technical articles
   D. Establish mailing list

II. Formulate list of perceived industrial needs

III. Design survey form

   A. Questions based on needs
   B. Test survey form on small sample
   C. Mail to established lists

IV. Data analyses

A. Compile data
B. Establish logical groups for data
C. Statistical analysis of data
D. Prioritize the needs

V. Implement follow-up on needs analyses

A. Consult with respondents
B. Decision on role of NCEMT

This report summarizes the results of each of the activities above, with major emphasis on the analysis of data obtained from the mail survey of industry.

2.0 INDUSTRY FAMILIARIZATION

2.1 BACKGROUND

Water jet cutting for manufacturing operations evolved from low pressure applications in mining and ore preparation. Breakthroughs in pump systems and nozzles complemented each other and led to modern high pressure (up to 60,000 psi) systems.

The use of a high pressure water jet to cut corrugated boxboard, building materials (e.g. fiberglass insulation) and plastics became commercially available in the early 1970's. High pressure water is forced through a small (.003 to .018" in diameter) nozzle and is typically guided by a robotic manipulator with a CNC control system.

In the early 1980's abrasives such as garnet, silica and aluminum oxide were added to the jet and water jet cutting (WJC) became abrasive jet machining (AJM). The addition of abrasives to the jet expanded the list of materials which could be cut using the new technology. Cutting Tool Engineering, April 1987, lists the following features of abrasive jet machining (AJM).

- ability to quickly and cleanly cut virtually any material, suiting it for tough-to-machine alloys and exotics, as well as composite and stringy materials that tend to smear and tear with conventional cutting tools
- low levels of airborne dust
- clean, high quality cuts with no heat-affected zone or dimensional distortion
- small kerf, which is particularly desirable for cutting expensive alloys and materials used in electronic circuit boards
- low cutting forces

- utilization of inexpensive, inexhaustible water and plentiful abrasives instead of expensive, consumable cutting tools

- lends itself to CNC control and robotic manipulation, omni-directional cutting

A typical abrasive jet machining system consists of the following components:

- water conditioning system

- high pressure intensifier pumping system with check valves and accumulator

- high pressure tubing and/or swivel connectors for transporting high pressure water to the cutting head

- synthetic sapphire jet nozzle

- abrasive system for introducing the abrasive to the jet flow stream
- a jet catcher to absorb the jet energy and collect the used abrasive

- an x-y table or roootic manipulator with a control system

Water jet cutting (WJC) and abrasive jet machining (AJM) systems have found a wide variety of cutting applications including the following partial list:

food, paper and corrugated board, shoe and garment materials, building materials, aluminum, lead, plastics, graphite, epoxy, Kevlar, fiberglass, titanium, steel, composites, magnesium, armor plate, tool steel, inconel, rubber, glass

However, it is widely believed that this technology has yet to reach its full potential.

2.2 REVIEW OF THE LITERATURE

A thorough and complete search of the technical literature has been conducted in the field of high pressure water jet technology. As a result of this research, NCEMT now has on hand virtually everything that has been written about water jet cutting, including papers, articles, and monographs as well as books. Much of this materials has been digested and an annotated bibliography will be developed as part of the NCEMT databases. A representative bibliography is given in Appendix A.

2.3 MEETINGS AND CONFERENCES

Further familiarization with the industry was developed through attendance at two conferences and a short course on water jet cutting:

a. American Society of Mechanical Engineers
Manufacturing International Conference
sessions on Non-Traditional Manufacturing Processes
Atlanta, GA, April 17-19, 1988

b. Society of Manufacturing Engineers
Automated Waterjet Cutting Processes
Detroit, MI, May 10-11, 1988

c. University of Missouri - Rolla
Short Course on Waterjet Technology
November 7-8, 1988

Some observations on the state of the industry, resulting from these contacts, follow:

At this stage the WJC community in manufacturing is rather small, and that of the academicians is even smaller.

The technology is still in its early stages of development. Consequently, the knowledge base is limited. In fact, the base is one of "send or bring your sample and we will see if WJC will do the job." Probably the most needed data set at this time is one that provides basic information on WJC, similar to that available on feeds and speeds for lathe operations. Until this type of information becomes available, the technology must depend on a lot of "blacksmithing." The manufacturing industry will develop some of these data from their WJC operations, but it will not be documented unless an outside organization takes on the responsibility of acting as a depository for the data. This is a logical task for NCEMT.

Laboratory space should be assigned for a WJC facility that could be used to conduct controlled studies of WJC processes. Initial studies should be designed to include experiments that will contribute to establishing a workable data base that defines the WJC parameters for cutting various types of materials and specimens. This endeavor should help to eliminate some of the "cut and try" effort required to respond to immediate needs.

One interesting application involved water jet assisted metal turning on a conventional lathe. Tests have been conducted on 41.3 / 36.5 mm pipe made of UNS 1020 steel, which is classified as a material with poor machinability. With a high pressure water jet of 0.25 mm diameter, good chip formation was realized at cutting speeds of 180 m/min. For these tests the feed force was reduced by approximately 50%, and the cutting force by approximately 23%, and total energy requirements were reduced. It is anticipated that this process will extend tool life by several orders of magnitude over that realized in non-water jet assisted cutting.

Another interesting application involved material pulverization by a cavitating high pressure water jet. To date, this device has been used only to generate coal slurry, but it may have potential for powder making applications in the powder metallurgy industry.

The high pressure water jet technology is developing at a rapid pace because of its short history in the metal working industry, but its potential is being exploited in only a limited number of applications. These applications are predominately situations in which conventional cutting methods have failed or resulted in damage to the material being processed. To justify replacing a conventional metal cutting application with a high pressure water jet usually requires a feasibility study to compare the economics of the entire process. These studies should start with metal stock and continue through all the required operations to the finished product. This type of analysis is necessary because the savings realized from high pressure water jet compared with conventional cutting techniques, in some cases, is the reduced preparation and finishing time required after cutting.

2.4 SHIPYARD VISITS

As part of the NCEMT survey of metalworking industry needs, visits were made to private and Navy shipyards. Sites visited included Bath Iron Works, Electric Boat Division of General Dynamics, Newport News shipbuilding, Ingalls Shipyard, Mare Island Naval Shipyard and Puget Sound Naval Shipyard. In addition, discussions were held with personnel at other shipyards, the David Taylor Research Center and NAVSEA.

During these visits, as part of the overall fact-finding mission, ongoing or anticipated applications of waterjet cutting in shipbuilding and repair were sought. In the sites visited, only one operating system was observed. This system was used at Puget Sound to cut lead on rubber sheet for gaskets. There seemed to be little interest in plate cutting or other applications at all shipyards.

3.0 A TENTATIVE LIST OF INDUSTRY NEEDS

From the various contacts at meetings and the published literature, a tentative list of WJC industry needs was drafted. An attempt was made to generalize these needs based upon the wide array of problems which were presented.

TENTATIVE INDUSTRY NEEDS LIST
WATER JET AND ABRASIVE JET CUTTING

1. SCIENCE - better understanding of how the process works

2. INDUSTRY STANDARDS - fittings, connectors, ratings, etc.

3. SAFETY STANDARDS - operator hazards, particulate overspray

4. ABRASIVE HANDLING SYSTEMS - current systems need improvement

5. SYSTEM INTEGRATION - robots, jet cutting system, water treatment, tooling design, etc.

6. CATCHER DEVELOPMENT - small, light weight jet catching devices

7. NOISE CONTROL - pump noise, water jet noise

8. TRAINING - operator, service, user training required

9. SERVICE - more and better service for robots and water jet systems

10. TOOLING - design philosophy for tooling is different because of low forces

11. HIGH PRESSURE QUICK DISCONNECT - none exist currently

12. ABRASIVE DUST CONTROL - fine abrasive dust is generated during abrasive jet cutting

13. HIGH PRESSURE SWIVELS - current swivels cost approximately $1,000 and last approximately 1,000 hours

14. WATER CONDITIONING STANDARDS

4.0 MAIL SURVEY

4.1 MAIL SURVEY FORM

The survey questionnaire was designed for quick response by industrial participants and for ease of numerically digesting the data. The survey form is given in Appendix B.

This form contains questions in six major groups. The first group concerns organizational questions. The remaining groups contain questions about WJC and include research and development, standards, systems, new products, and training and service. All of the questions relating directly to WJC are provided with a numerical scale ranging from 0 to 5.

4.2 FORM EVALUATION

Both the cover letter and the survey form were tested on a small (approximately 20 people) audience. Each of these volunteers was instructed to critique both the letter and the survey form. This exercise proved to be very valuable. Most of the test group made very constructive suggestions. All of the suggestions, corrections, and changes were carefully considered and the survey form and cover letter were finalized.

4.3 IMPLEMENTATION OF THE SURVEY

Three lists of people were selected to receive the survey forms. The first group consisted of the 103 attendees at the SME sponsored clinic entitled "Automated Water Jet Cutting Processes." The second list consisted of the 380 attendees at the ASME sponsored conference entitled, "Manufacturing International '88." The third group of names was acquired from the Naval Industrial Resources Support Activity office and represents the mailing list for the Navy Manufacturing Technology Program Report. This list includes 900 names.

Each of these lists represents a different constituency. The first list represents people already vitally interested in water jet cutting. It was known before the survey that this group would provide a good number of users as well as manufacturers of water jet cutting equipment. The second list was believed to include a broad spectrum of people with interests in manufacturing. It was also known that this group included a fair number of academicians. The third list represented DOD and included many DOD contractors.

The first and second lists were entered into a computer database and the Naval Industrial Support Activity office of the Navy supplied mailing labels for the third list.

The survey form, cover letter, postage paid return envelope, and a pamphlet describing NCEMT were mailed to all of the people on each of the three mailing lists during July, 1988.

Survey forms were returned to the Center throughout August and September, 1988. Sometimes the forms were accompanied by information about the respondents organization or other piece of pertinent information.

The return envelopes and survey forms were marked with a code so that respondents could be correlated with their respective mailing lists.

All of the data from the returned survey forms was entered into a computer database for analysis of the results.

The survey respondents are divided into two categories: participants and non-participants. The non-participants are individuals that responded in order to receive a copy of this report, but disqualified themselves as participants for lack of familiarity with WJC. Table I contains a summary of the respondents for each mailing list.

TABLE I

Mailing List	List Population	Participants	Non-Participants	Total No. Respondents
SME HPWJ Clinic	103	45	2	47
ASME Manuf. International	380	36	5	41
U.S. Navy	900	91	16	107
Totals	1,383	172	23	195

As expected, the SME HPWJ clinic participants provided the highest percentage of respondents because the survey was designed for this special topic.

5.0 RESULTS

5.1 SURVEY DATA

5.1.1 Organizational Questions

The results for the organizational questions are provided in Figure 1. The vertical scale is the fractional value calculated from the responses for each group of respondents. The letters along the horizontal axis correspond to the questions labeled beneath the figure (questions from Page 1 of the survey form). The numerical values adjacent to each question are those calculated for each respondent grouping and plotted in Figure 1.

From this figure it is interesting to note that:

1. 80% of all respondents are involved with defense contracting.

2. 40% of all respondents are WJC users.

3. 59% of all respondents and 64% of the respondents that are neither users or suppliers are considering a WJC system.

4. 91% of all respondents are seeking more information about WJC.

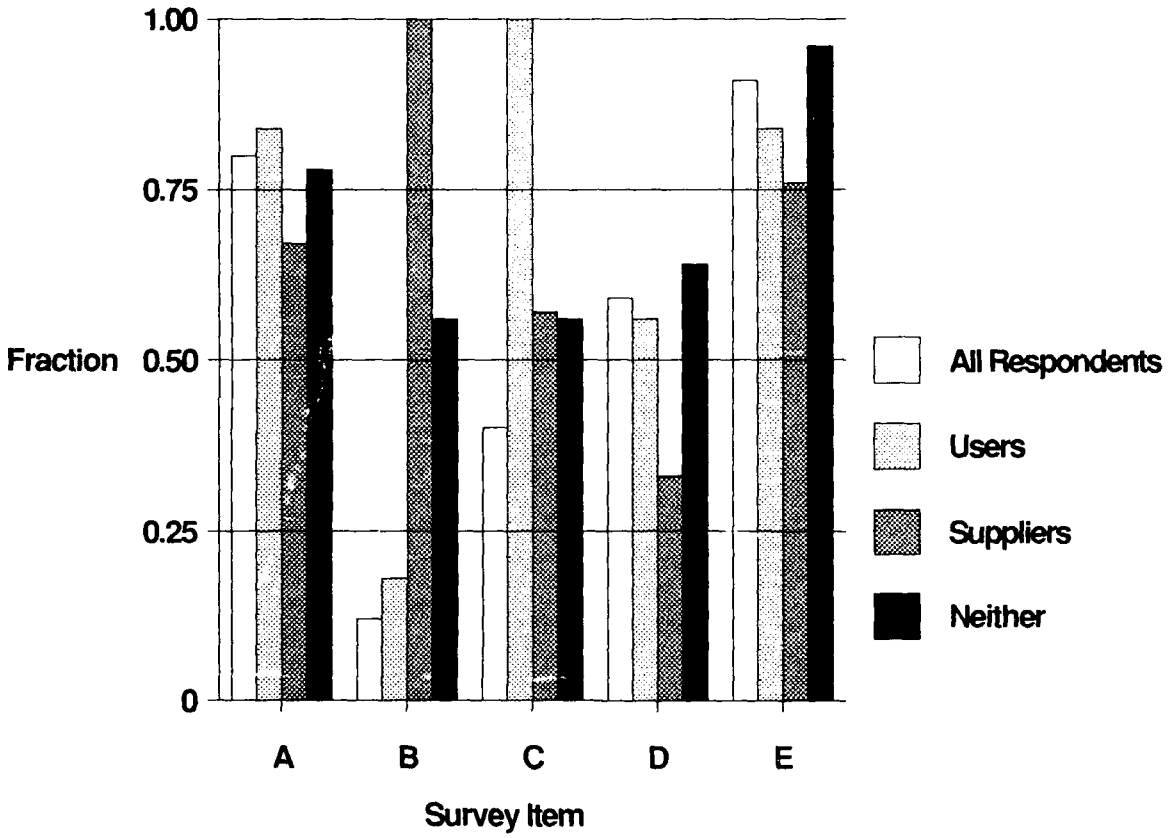
5.1.2 WJC Technology Questions

This part of the survey addresses five specific areas of WJC technology. These are 1) research and development, 2) standards, 3) systems, 4) new products, and 5) training and service. Respondents were requested to answer the questions on the priority scale provided. The scale range is from 0 to 5 (0 designates the lowest priority and 5 designates the highest priority). The needs were ranked on the following priority scale:

Needs Ranking	Priority Mean Value
High priority	4.0 or greater
Important	3.5 to 4.0
Attention is required	3.0 to 3.5
Low priority	less than 3.0

Graphical and numerical results for questions in this category are given in Figures 2 through 6. The numerical values on the vertical axis represent the mean values for the priority. The roman-arabic numerals along the horizontal axis correspond to the survey subject areas and question numbers, respectively.

Organizational Questions



Survey Item	Respondent Group No. 1 All	2 Users	3 Supp.	4 Neither
Is your organization				
A. Involved with defense contracting?	0.80	0.84	0.67	0.78
B. A supplier of water jet or abrasive jet cutting systems or components?	0.12	0.18	1.00	0.56
C. Using water jet or abrasive jet cutting?	0.40	1.00	0.57	0.56
D. Considering a water jet cutting system?	0.59	0.56	0.33	0.64
E. Seeking more information about water jet cutting?	0.91	0.84	0.76	0.96

Figure 1

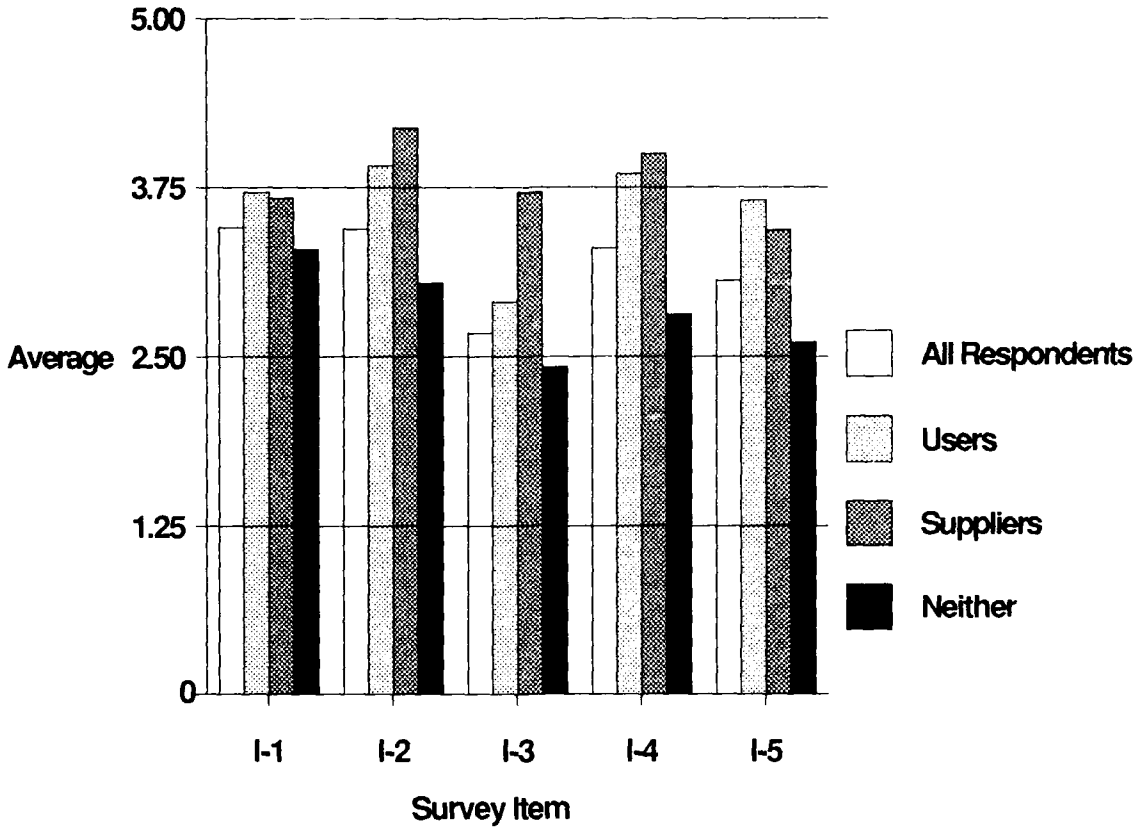
5.1.3 Research and Development

For this group of items the response of WJC users and suppliers is considered a good indicator for the future direction of developments in WJC technology. These trends can be observed in Figure 2 which contains both the graphical and tabulated results of the items in the research and development category. A summary of the responses is as follows:

Item		Users	Suppliers
1.	Basic research on cutting principles	Important	Important
2.	High pressure nozzle design	Important	High Priority
3.	Intensifer pump design	Low priority	Important
4.	Abrasive injection systems	Important	High priority
5.	Jet catcher development	Important	Attention is required

Item 3 is the only area in which there is a significant disagreement in the responses of the WJC suppliers and users.

Research and Development Needs



Survey Item	Respondent Group No. 1 All	2 Users	3 Supp.	4 Neither
I. Research and Development				
1. Basic Research on Cutting Principles	3.45	3.71	3.67	3.29
2. High Pressure Nozzle Design	3.44	3.91	4.19	3.04
3. Intensifier Pump Improvement	2.67	2.90	3.71	2.42
4. Abrasive Injection Systems	3.30	3.85	4.00	2.81
5. Jet Catching Development	3.06	3.65	3.43	2.60

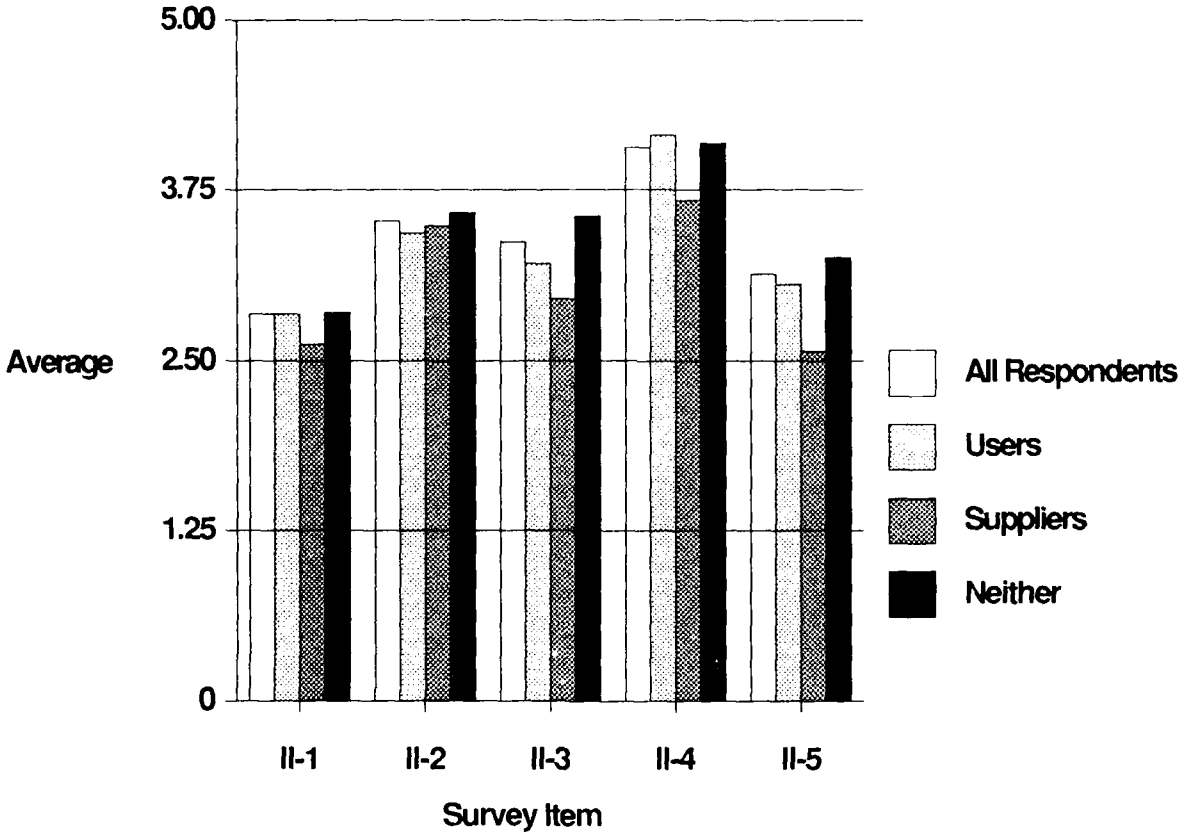
Figure 2

5.1.4 Standards

The results for the responses in this group of questions are given in Figure 3. The response of all the combined groups appear to be fairly indicative of the priority ratings for the items in the standards list. The ordered priority ratings are:

Item		All Respondents
4.	Performance standards	High priority
2.	Safety standards	Important
3.	Environmental standards	Attention is required
5.	Standardized system specs.	Attention is required
1.	Hardware standards	Low priority

Standards



Survey Item	Respondent Group No. 1 All	2 Users	3 Supp.	4 Neither
II. Standards				
1. Hardware Standards	2.84	2.84	2.62	2.85
2. Safety Standards	3.52	3.43	3.48	3.58
3. Environmental Standards (e.g. Noise, Moisture, etc.)	3.37	3.21	2.95	3.55
4. Performance Standards (Cutting Speeds, Tolerances, Finish, etc.)	4.06	4.15	3.67	4.09
5. Standardized System Specs.	3.13	3.06	2.57	3.25

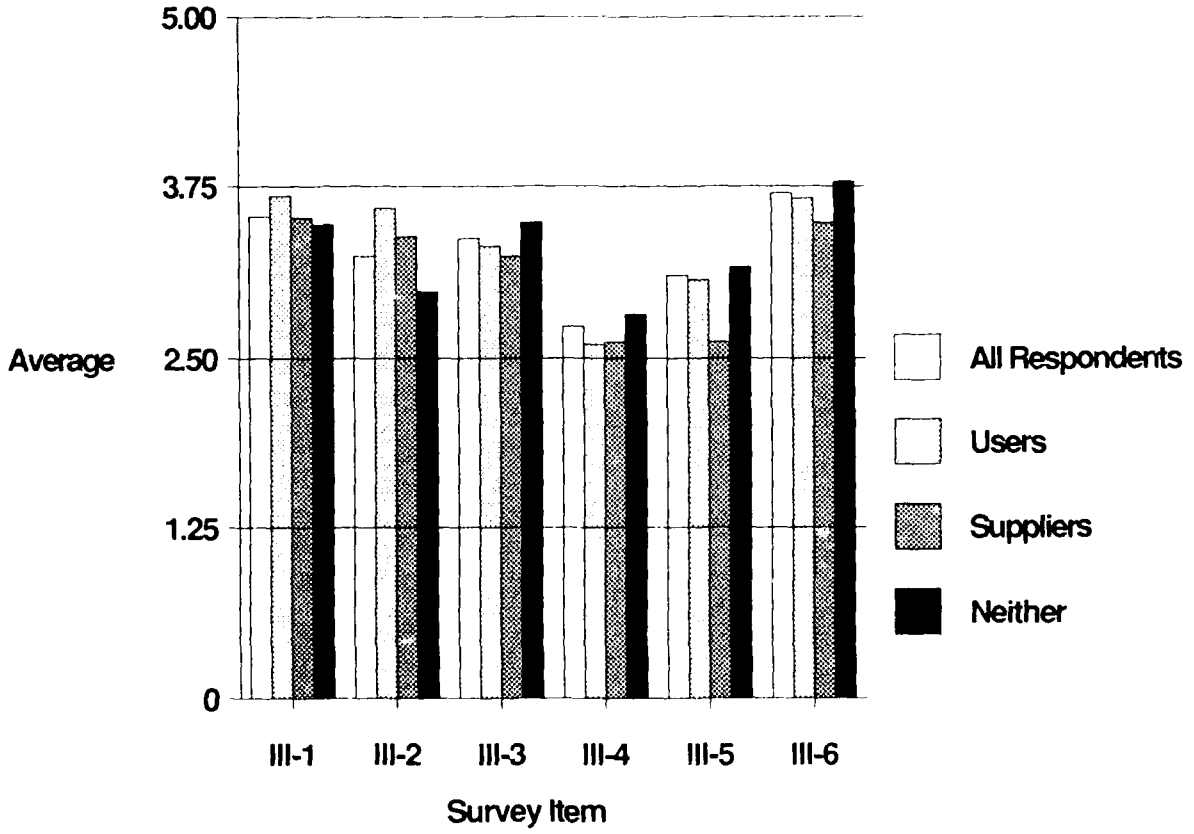
Figure 3

5.1.5 Systems

None of the items in this group were given a high priority rating. Both Items 1 (system integration) and 6 (robotics or NC controller systems) are rated as being important on the priority scale. Note that these items are closely related. The respondents in the users group consider item 2 to be important. The users probably have a better feel for the problems involved with abrasive handling systems than other respondent groups. Therefore, their opinion would dictate the priority of this item. The graphical and numerical results are given in Figure 4. The priority order for the system category is as follows:

	ITEM	PRIORITY
1.	Systems Integration	Important
6.	Robotic or NC controller system	Important
2.	Abrasive handling systems	Important
3.	Tool design	Attention is required
5.	Disposal systems	Attention is required
4.	Water conditioning systems	Low priority

Systems Needs



Survey Item	Respondent Group No. 1 All	2 Users	3 Supp.	4 Neither
III. Systems				
1. System Integration	3.53	3.68	3.52	3.47
2. Abrasive Handling Systems	3.24	3.59	3.38	2.98
3. Tooling Design	3.37	3.31	3.24	3.48
4. Water Conditioning Systems	2.73	2.60	2.62	2.82
5. Disposal Systems	3.10	3.07	2.62	3.16
6. Robotic or NC Controller Systems	3.70	3.66	3.48	3.78

Figure 4

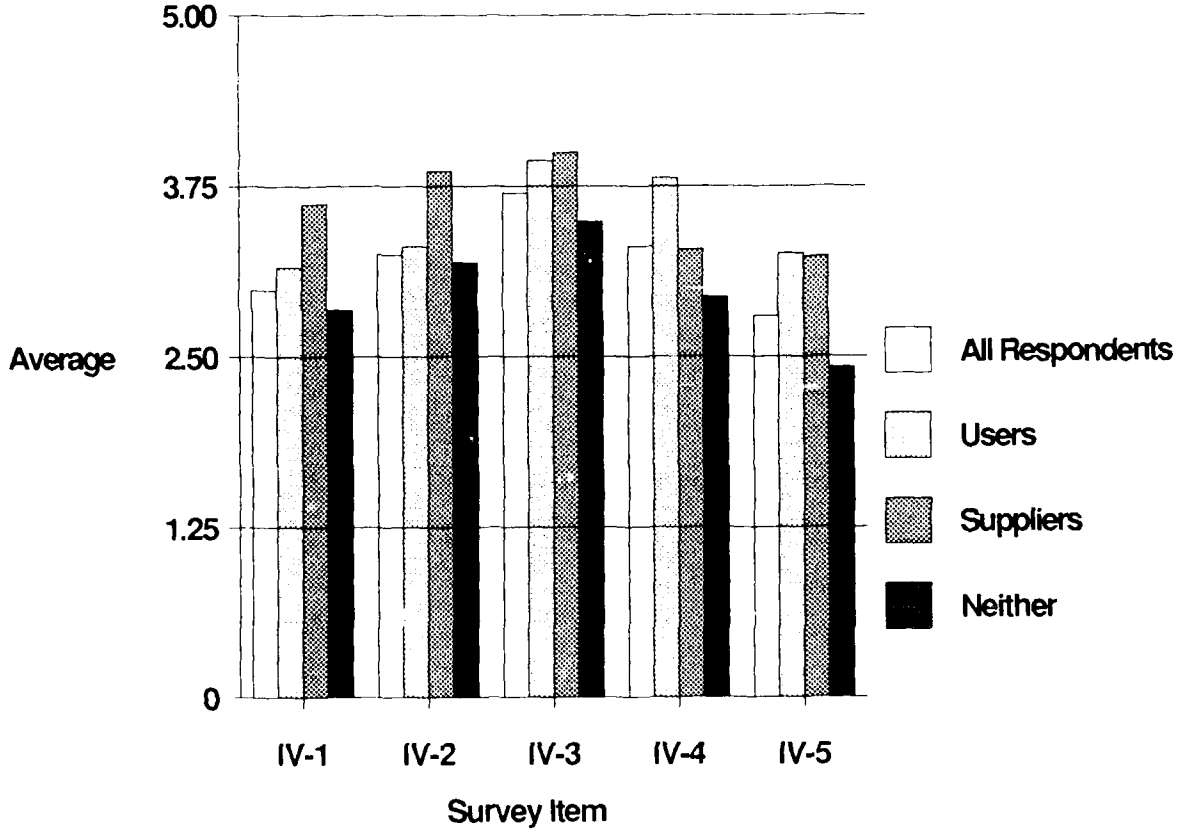
5.1.6 New Products

This category of items is a "mixed bag." It is difficult to decide how to treat the opinions of those respondents that are neither users nor suppliers of WJC equipment. The survey was not designed to establish the respondents level of knowledge about the survey material. Consequently, the response of only the users and suppliers of WJC equipment will be used to set the priority for these items. The graphical and numerical results are given in Figure 5. A summary of the users and suppliers priorities is:

Item		Users	Suppliers
1.	High pressure quick disconnects for	Attention is required	Important
2.	High pressure swivel joints with longer service life	Attention is required	Important
3.	Automatic nozzle alignment system for abrasive jet nozzles	Important	High priority
4.	Jet catchers that operate in all positions	Important	Attention is required
5.	Transport system for abrasives	Attention is required	Attention is required

It is interesting that the suppliers give Item 1 a higher priority rating than the users. The difference in the priority rating for Item 4 is understandable since suppliers are not generally as concerned with multi-position cutting as users are.

New Products



Survey Item	Respondent Group No. 1 All	2 Users	3 Supp.	4 Neither
IV. New Products				
1. High Pressure Quick Disconnects for Robot Tool Change	2.99	3.16	3.62	2.84
2. High Pressure Swivel Joints with Longer Service Life	3.25	3.31	3.86	3.19
3. Automatic Nozzle Alignment System for Abrasive Jet Nozzles	3.70	3.94	4.00	3.49
4. Jet Catchers that Operate in all Positions	3.31	3.81	3.29	2.94
5. Transport System for Abrasives	2.80	3.26	3.24	2.42

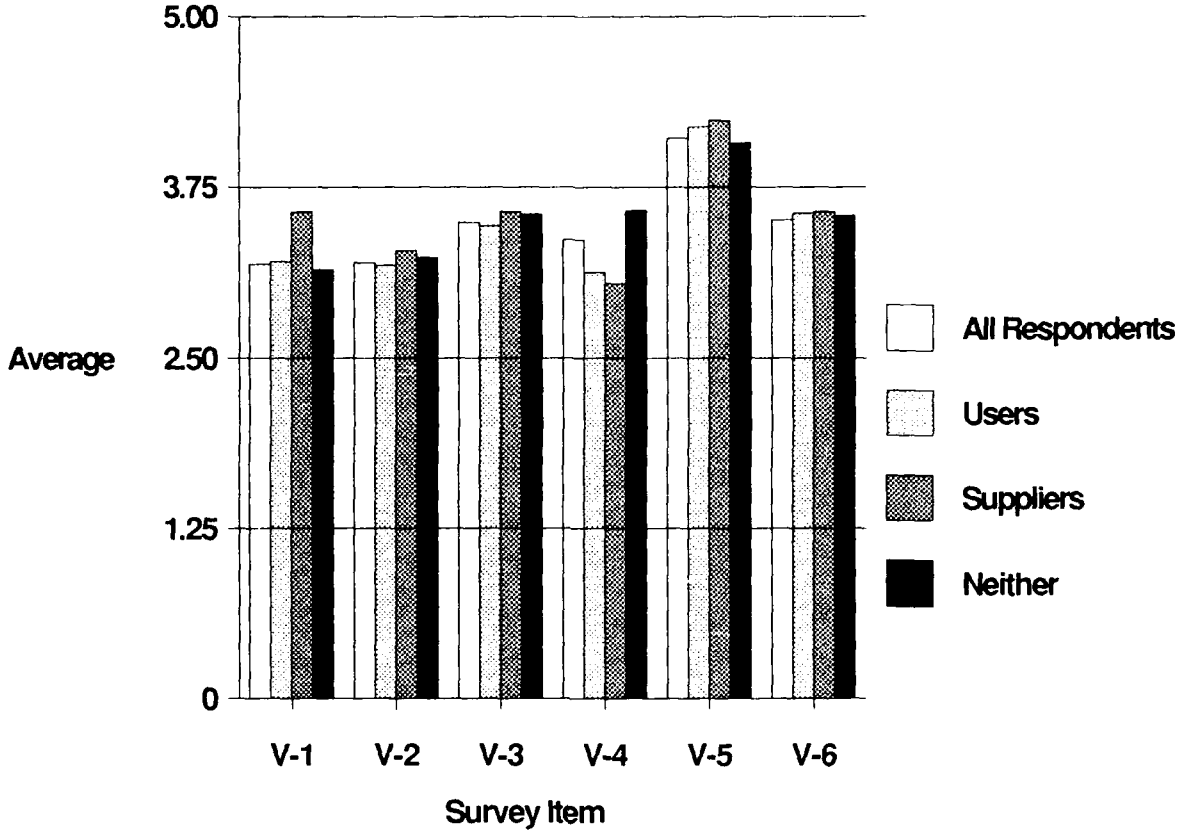
Figure 5

5.1.7 Training and Service

There is very little spread in the responses to the items in this category. There is an interesting little anomaly in the responses to Items 1 (operator tra ning) and 4 (short courses for potential users). The suppliers rank Item 1 at a value of 3.57 and Item 4 at a value of 3.05. Whereas, the respondents in the neither category rate these items at 3.15 and 3.58 respectively. Suppliers want operator training to teach users proper equipment operation and maintenance, and respondents in the neither category want short courses to better understand WJC technology. Both of these items should be rated as important. The graphical and numerical results are given in Figure 6. A summary of the ordered priorities is as follows:

	ITEM	PRIORITY	RESP. GR.
5.	Handbook with cutting data for various materials	High priority	All
4.	Short courses for potential users	Important	Neither
1.	Operator training	Important	Suppliers
6.	Water jet cutting test and demonstration	Important	All
3.	Manufacturing engineering training	Important	All
2.	Maintenance training	Attention is required	All

Training and Service



Survey Item	Respondent Group No. 1 All	2 Users	3 Supp.	4 Neither
V. Training and Service				
1. Operator Training	3.19	3.21	3.57	3.15
2. Maintenance Training	3.20	3.18	3.29	3.24
3. Manufacturing Engineering Training	3.49	3.47	3.57	3.55
4. Short Courses for Potential Users	3.37	3.13	3.05	3.58
5. Handbook with Cutting Data for Various Materials	4.11	4.19	4.24	4.07
6. Water Jet Cutting Test and Demonstration Center	3.51	3.56	3.57	3.54

Figure 6

5.2 PRIORITY LISTING OF SURVEY ITEMS

This listing is based on the above results with the various items presented in a decending priority order independent of the category.

High Priority Items

		Resp. Gr.	Mean Value
V-5.	Handbook with cutting data for various materials	All	4.11
II-4.	Performance standards	All	4.06

Important Items

		Resp. Gr.	Mean Value
IV-3.	Automatic nozzle alignment system for abrasive jet nozzles	Users & Suppliers	3.96
I-2.	High pressure nozzle design	Users & Suppliers	3.95
I-4.	Abrasive injection system	Users & Suppliers	3.91
IV-4.	Jet catchers that operate all positions	Users & Suppliers	3.78
III-1.	System integration	Users	3.68
III-6.	Robotic or NC controller systems	Users	3.66

I-1.	Basic research on cutting principles	Users & Suppliers	3.66
I-5.	Jet catcher development	Users & Suppliers	3.64
III-2.	Abrasive handling system	Users	3.59
V-4.	Short courses for potential users	Neither	3.58
V-1.	Operator training	Suppliers	3.57
II-2.	Safety standards	All	3.52
V-6.	Water jet cutting test and demonstration center	All	3.51

Attention is Required Items

		Resp. Gr.	Mean Value
V-3.	Manufacturing engineering training	All	3.49
III-3.	Tool designing	All	3.37
II-3.	Environmental standards	All	3.37
IV-2.	High pressure swivel joints with longer service life	Users & Suppliers	3.33
IV-5.	Transport system for abrasives	Users & Suppliers	3.28
V-2.	Maintenance training	All	3.20

IV-1.	High pressure quick disconnects for robot tool changes	Users & Suppliers	3.17
II-5.	Standardized system specs.	All	3.13
III-5.	Disposal system	All	3.10

Low Priority Items

		Resp. Gr.	Mean Value
I-3.	Intensifer pump improvement	Users & Suppliers	2.99
II-1.	Hardware standards	All	2.84
III-4.	Water conditioning systems	All	2.73

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 SURVEY CONCLUSIONS

The results of this survey show a high priority need to establish:

- A data base on water jet cutting that contains the necessary technical data (i.e. nozzle size, pump pressures, abrasive type, nozzle speed, etc.) for cutting various types of metals using high pressure water jets; this information must be made available to the entire WJC community.

In addition, the results indicate there is an important need:

- To establish a WJC demonstration center that can be used for cutting tests, short courses for potential users, and operator training;

- To establish organized efforts in hardware development which should include automatic nozzle alignment, abrasive injection and handling systems, jet catchers, system integration, and basic research on cutting principles.

The National Center for Excellence in Metalworking Technology (NCEMT) wishes to solicit suggestions from interested individuals in the water jet cutting community on ways to initiate action to address these issues.

It is recommended that:

1. A directed effort be made to centralize the collection of WJC data

2. An on-line computerized database be established which would be available to the WJC community

3. A WJC facility be designated to generate the data needed to complete the database, provide demonstrations, and assist in the improvement and development of WJC hardware

4. A workshop of interested people in the WJC community be convened to define the format of the water jet cutting database and the parameters to be included in the database

6.2 RECOMMENDED NAVY USES

Although Waterjet Cutting (WJC) and Abrasive Waterjet Cutting (AWJ) are, at present, not extensively used in Navy shipyards, they have tremendous potential for many applications. Applications commonplace to shipyards which are ideal for WJC and AWJ are complex shape cutting, thick section cutting requiring low thermal distortion, and preparation of faying surfaces without additional processing for welding. The expected increase in use of titanium in shipbuilding, with its tendency for thermal distortion, may require increased use of WJC for plate cutting. WJC and AWJ are extremely useful for manufacturing parts with complex geometry due to limited tooling requirements and ease of access to the cutting stream. Relatively thick sections of material may be cut without the need for post process heat treatment. Unlike plasma cutting, in general use at shipyards, WJC and AWJ leave faying surfaces ready for welding in the as-cut condition.

The presence of a waterjet system at the NCEMT would provide immediate benefits to Navy programs and shipyards. NCEMT would be able to establish a training course for equipment users at a single location. This would help overcome problems associated with high personnel turnover in government shipyards. NCEMT has a unique ability to assist in the development of prototype tooling in WJC and AWJ fixturing. Using the latest in Direct Numeric Controlled machining and Computer Integrated Manufacturing technology, NCEMT can design and fabricate developmental fixtures for any anticipated waterjet application. Finally, NCEMT could provide technical support for equipment and process development.

APPENDIX A

BIBLIOGRAPHY

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APPENDIX B

SURVEY FORM AND COVER LETTER

Metalworking Technology Inc.
A nonprofit subsidiary at the University of Pittsburgh, Johnstown

NCEMT

National Center for Excellence in Metalworking Technology
East Hills Professional Building
1450 Scalp Avenue, Johnstown, PA 15904
Telephone (814) 266-2874; Fax 814-266-5106

MEMO FROM: NATIONAL CENTER FOR EXCELLENCE IN METALWORKING TECHNOLOGY

DATE: July 18, 1988

SUBJECT: WATER JET CUTTING INDUSTRIAL SURVEY

The National Center for Excellence in Metalworking Technology (NCEMT) has been established by the U. S. Navy as part of the Navy's MANTECH program. This program is targeted to provide information and support for the nation's manufacturing effort. The Center has been assigned the responsibility to help industry in the area of metalworking. (The enclosed pamphlet will give you more information about the Center.)

One area of particular interest for the Center is nontraditional machining and we are currently conducting an industrial needs analysis of the new and growing field of water jet cutting. You can help in this effort by completing the enclosed survey form and returning it in the enclosed postage paid envelope. The information you provide will help us here at the Center in our analysis of this important industry.

As an incentive for those who participate, we will send a copy of the water jet cutting industrial needs analysis report to all who mail in their survey forms. This report will indicate what knowledgeable people throughout the industry regard as the highest priority needs and should prove to be of great value to you and your organization. It is anticipated that this report will be available in late September.

Please accept our thanks and appreciation for helping to bring about a better understanding of an important American industry.

JGK/cz
Enclosures

NCEMT

NATIONAL CENTER FOR EXCELLENCE IN METALWORKING TECHNOLOGY

WATER JET CUTTING INDUSTRY SURVEY

NAME:_____ DATE:_____

TITLE: _____

COMPANY: _____

ADDRESS: _____ PHONE NO.: (_____)-_____

_____

_____

_____

BRIEF DESCRIPTION OF BUSINESS (PRODUCTS, SERVICES, etc.):

_____

_____

_____

NUMBER OF EMPLOYEES AT YOUR LOCATION:

Under 50	_____
50-100	_____
100-200	_____
200-400	_____
Over 400	_____

IS YOUR ORGANIZATION

a. INVOLVED WITH DEFENSE CONTRACTING? YES___ NO___

b. A SUPPLIER OF WATER JET OR ABRASIVE JET CUTTING SYSTEMS OR COMPONENTS? YES___ NO___

c. USING WATER JET OR ABRASIVE JET CUTTING? YES___ NO___
IF YES TO (c.) LIST MATERIALS YOU ARE CURRENTLY CUTTING
_____

d. CONSIDERING A WATER JET CUTTING SYSTEM? YES___ NO___

e. SEEKING MORE INFORMATION ABOUT WATER JET CUTTING? YES___ NO___

Rev. 7-18-88

INDICATE YOUR OPINION OF THE PRIORITY OF THE NEEDS OF WATER JET CUTTING TECHNOLOGY IN THE METALWORKING INDUSTRY. PLEASE FEEL FREE TO ADD AS MANY ADDITIONAL NEEDS AS YOU SEE FIT.

	NO OPINION	LOWEST PRIORITY				HIGHEST PRIORITY
I. RESEARCH AND DEVELOPMENT						
1. basic research on cutting principles	0	1	2	3	4	5
2. high pressure nozzle design	0	1	2	3	4	5
3. intensifier pump improvement	0	1	2	3	4	5
4. abrasive injection systems	0	1	2	3	4	5
5. jet catching development	0	1	2	3	4	5
6. other _____	0	1	2	3	4	5
II. STANDARDS						
1. hardware standards	0	1	2	3	4	5
2. safety standards	0	1	2	3	4	5
3. environmental standards (e.g. noise, moisture, etc.)	0	1	2	3	4	5
4. performance standards (cutting speeds, tolerances, finish, etc.)	0	1	2	3	4	5
5. standardized system specs.	0	1	2	3	4	5
6. other _____	0	1	2	3	4	5
III. SYSTEMS						
1. system integration	0	1	2	3	4	5
2. abrasive handling systems	0	1	2	3	4	5
3. tooling design	0	1	2	3	4	5
4. water conditioning systems	0	1	2	3	4	5
5. disposal systems	0	1	2	3	4	5
6. robotic or NC controller systems	0	1	2	3	4	5
7. other _____	0	1	2	3	4	5

IV. NEW PRODUCTS	NO OPINION	LOWEST PRIORITY				HIGHEST PRIORITY
1. high pressure quick disconnects for robot tool changes	0	1	2	3	4	5
2. high pressure swivel joints with longer service life	0	1	2	3	4	5
3. automatic nozzle alignment system for abrasive jet nozzles	0	1	2	3	4	5
4. jet catchers that operate in all positions	0	1	2	3	4	5
5. transport system for abrasives	0	1	2	3	4	5
6. other _____	0	1	2	3	4	5
V. TRAINING AND SERVICE						
1. operator training	0	1	2	3	4	5
2. maintenance training	0	1	2	3	4	5
3. manufacturing engineering training	0	1	2	3	4	5
4. short courses for potential users	0	1	2	3	4	5
5. handbook with cutting data for various materials	0	1	2	3	4	5
6. water jet cutting test and demonstration center	0	1	2	3	4	5
7. other _____	0	1	2	3	4	5

VI. ADDITIONAL COMMENTS

_____

_____

_____

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_____